

AUTOMATIC FRAME IDENTIFICATION, DOOR STATUS, AND FRAME COUNT

DETECTION SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

5 The present invention relates to an automatic identification, operational status and count detection system that is part of a modular system of components. In particular, the present invention relates to an automatic frame identification, door status and frame count detection system to enable a modular system such as a tape library system having multiple independent frames to automatically identify each frame in the library and to detect that frame's operational status. The particular utility for the present invention is in modular tape library systems, such as 10 IBM's 3584 tape library system, although the present invention has general applicability to the identification and operational status detection of any modular system.

2. Description of Related Art

15 Conventional modular multi-frame tape library systems such as the IBM 3494 comprise a plurality of frames connected together to form a tape library. Typically, each frame includes the necessary hardware and software to operate those components of that frame which may include a plurality of tapes, a plurality of tape drive mechanisms for reading and writing data to tapes, and one or more controllable robot members to move tapes to and from tape drive mechanisms. The 20 details of the tapes, tape drives, and robotic members are not important for an understanding of the present invention.

When frames are added together in such systems, it is desirable for methodology in place to identify each frame in the library system. Additionally, it may also be desirable to generate data related to the operational status of each frame within the library. For example, typically

frames include outer doors which are opened when that frame is, e.g.; under repair. Such data may be critical since if a frame is inadvertently brought on-line while a repairman is inside, serious injury may result. Conventional techniques of identifying each frame within the library include a manual configuration system where each frame obtains a separate identification using,

5 for example, dip switch settings or address switches which provide a unique identifier to the individual member frames of the tape library. Additionally, in conventional systems when a door of a frame is opened, the entire system needs to be re-inventoried so that an accurate count and operational characteristics of each frame is obtained. When an additional frame member is added to an existing multi-frame library, conventional identification systems require a manual 10 reconfiguration of all the individual frame members to obtain an accurate identification of all the frame members in the library. In such conventional systems, the individual frame members are linked together via a common data bus and the identification and operational status information is stored on a master status register. Thus, in such conventional systems, the individual frame members do not possess the identity and operational characteristics of other frame members 15 within the library.

Thus, there exists a need for a modular tape library system that is adapted to automatically identify and detect the operational status of the individual frame members of the tape library. There also exists a need for the individual frame members of the tape library to track and store data related to itself and the other frame members within the tape library system.

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SUMMARY OF THE INVENTION

Accordingly, one exemplary embodiment of the present invention provides a multi-frame tape library system, comprising a plurality of individual frames connected in series, each frame comprising a pulse signal generator and a delay signal generator. At least one of the frames also

includes a total count counter. The exemplary embodiment also includes a multi-channel bus coupled to each frame and comprising a power bus for carrying information indicative of power being supplied to a frame, and a power bus return bus carrying information indicative of the last frame in the series. One of the frames is defined as a first frame and adapted to receive a signal 5 indicative of power being supplied to any one of the frames and generate a delayed signal, each subsequent frame receives the delayed signal and generating a further delayed signal and a pulse on the frame bus. One of said frames is defined as the last frame and receives the delayed signal and generates a signal to activate said power return bus. The total count counter is incremented by each pulse on the frame bus until the power return bus is activated.

10 In this embodiment the total count of the number of frames in the library is identified by the incremental count in the total count counter representing the total number of frames connected together.

15 In another embodiment, the present invention provides a multi-frame tape library system, comprising a plurality of individual frames connected in series, each frame comprises a pulse signal generator and a delay signal generator. At least one frame also comprises an individual ID counter. This exemplary embodiment also provides a multi-channel bus coupled to each frame and comprising a frame bus for carrying information indicative of the presence of said frame. One of the frames is defined as a first frame and adapted to receive a signal indicative of power 20 being supplied to any one of the frames and generate a delayed signal, each subsequent frame receiving the delayed signal and generating a further delayed signal and each frame generating a pulse on said frame bus. At least one of the frames generates a frame pulse upon generation of that frame's delayed signal. The individual ID counter is incremented by each pulse on the frame bus until the frame pulse is detected.

In this embodiment the individual ID of the frame with the individual ID counter is identified by the incremental count in the individual ID counter with respect to the total number of frames connected together.

In method form, the present invention provides a method to automatically detect the total 5 count of frames within a modular multi-frame tape library system. The method includes the steps of: coupling a plurality of frames to a multi-channel data bus comprising a frame bus and a power bus return bus; designating one of said frames as a first frame; designating one of the frames as a last frame; the first frame receiving a signal indicative of power being supplied to any one of the frames and generating a first delayed signal and a pulse indicative of the presence 10 of the first frame; supplying the pulse to the frame bus; supplying the delayed signal to a subsequent frame, each said subsequent frame generating a delayed signal and a pulse indicative of the presence of each frame and supplying the pulses to the frame bus; generating a signal to activate the power return bus when the delayed signal reaches said last frame; and incrementing a register by each pulse until said power bus is activated.

Still other methods are provided. For example, in yet another exemplary embodiment, the present invention provides a method to automatically detect the individual identification of frames within a modular multi-frame tape library system. The method includes the steps of: coupling a plurality of frames to a multi-channel data bus comprising a frame bus; designating one of the frames as a first frame; the first frame receiving a signal indicative of power being supplied to any one of the frames and generating a first delayed signal and a pulse indicative of the presence of the first frame; supplying said pulse indicative of the presence of the first frame to said frame bus; supplying said delayed signal to a subsequent frame, each subsequent frame generating a delayed signal and a pulse indicative of the presence of each frame and supplying 20

the pulses to the frame bus; generating a signal upon generation of the delayed signal; and incrementing a register by each pulse until said signal is generated.

It will be appreciated by those skilled in the art that although the following detailed description will proceed with reference being made to exemplary embodiments and methods of use, the present invention is not intended to be limited to these exemplary embodiments and methods of use. Rather, the present invention is of broad scope and is intended to be limited only as set forth in the accompanying claims.

Other features of the present invention will become apparent to those skilled in the art as the following detailed description proceeds, and upon reference to the drawings, wherein like numerals depict like parts, and wherein:

Brief Description of the Drawings

Fig. 1 is an exemplary automatic frame identification and operational status system in a modular multi-frame tape library according to the present invention;

Fig. 2 is an exemplary timing diagram for frame identification, door status and total frame count of the system depicted in Fig. 1; and

Figures 3A-3D depict flowcharts of the exemplary frame detection, identification and status monitoring process according to the present invention.

Detailed Description of Exemplary Embodiments

Fig. 1 depicts an exemplary automatic frame identification and operational status system 10 in a modular multi-frame tape library according to the present invention. The exemplary system 10 includes a plurality of frames labeled Frame 1, Frame n-1 and Frame n which constitute a multi-frame tape library system 10. Each frame includes a pulse generator and delay signal generator circuit 12 and a may also include status register 14 (for clarity, only these

components for Frame 1 are labeled). The status register may include a plurality of counters and/or registers, and individual registers that could comprise, for example: a total count counter, an individual count counter and/or a status condition counter. Such counters are well-known in the art, and are thus omitted from the drawings for clarity. A multi-channel data bus 16

5 interconnects each individual frame member with one another. Except as otherwise indicated below, it is to be understood that the frame members are identical and may be interchangeable with one another, and further may be positioned in a different order than depicted in Fig. 1 (e.g., Frame n-1 can trade positional places with Frame n-2), where each frame will be identified in accordance with the following detailed description. The pulse generator and delay signal generator 12 and status register 14 associated with each frame and operable over the multi-channel data bus 16 permit each frame to automatically identify itself and other frame members in the tape library system 10 as well as operational characteristics of each frame member such as door open status and/or other operational characteristics of the frame library.

10 The first frame (Frame 1) and the last frame (Frame n) are typically identical in all respects with other frames within the library (e.g., Frame n-1), except as follows. In the present invention a delayed power signal is propagated through each member frame by a predetermined time constant. Thus, in the exemplary embodiment shown in Fig. 1 the first frame, and more particularly the pulse generator and delay signal generator 12 of Frame 1, receives a power on input signal 18, 18' or 18'' and is responsible for generating the first delayed signal 20 in the series. In each frame, and upon generation of the delayed pulse 20, circuit 12 also generates a frame bus signal and a door bus signal which are supplied to the Frame Bus signal line 24 and Door Bus signal line 26, respectively. Also, when a given delay circuit 12 generates a delay pulse, a frame pulse 30 is also generated and supplied to the status register for that frame. The

door status signal may also include a switch 32 that is activated if the door to a particular frame is open. The last frame in the series, frame n, generates a signal to the Power Return Bus 28, which indicates to all the frame members that no more pulses will be generated, and thus a total frame count can be calculated by each frame. The first frame in the series, frame 1, is designated 5 to first receive a power on signal 18 by any of the frames, via connection line 34 between the power bus 22 and the delay gate of the circuit 12, and generate the first delay signal 20 which is then propagated through each frame in the series. Otherwise, the operational characteristics of the functional components 12 and 14 are identical for each frame in the system. These and other characteristics of the present invention are described in greater detail below.

With reference now to the system 10 of Fig. 1, the foregoing characteristics of the pulse generator and upon application of a power, 18, 18' or 18'' in any of the frames, power on input signals represent a signal indicative of power being applied to that individual frame, respectively. Initial application of power (18, 18' or 18'') by any frame generates a reset signal to each status register (of each frame so-equipped), as shown by the two-way arrow coupling the power bus 22 to each register. In the exemplary embodiment, at least one register comprises a total count 10 counter for tracking the total number of frames in the system, and an individual counter for determining its own ID with respect to the other frames. Referring now to the timing diagram 40 of Figure 2, application of a power signal 18 supplied to the power bus 22 and supplied 34 to the first circuit 12 of the series is indicated at time T_0 . Circuit 12, 12' and 12'' each have a 15 predetermined time delay for generating the respective delay signal. At time T_1 , Frame 1 generates the delay signal 20, the frame bus signal 24 and a frame pulse 30. Similarly, frames n-1 and n generate respective delay signals (20' and 20'') and frame pulse signals (30' and 30''), as well as frame signals (24' and 24'') and, if appropriate, door bus signals (26' and 26'') at 20

times T_{n-1} and T_n , respectively. Also, the last frame at T_n generates a power bus return signal 28 which stops the count in each frame. At some predetermined later time, T_{n+m} , power is removed from each circuit 12, thus permitting another count (described below) upon a future application of a power signal in any frame.

5 Each frame is identified to itself (with respect to the other frame members) when the individual counter gets incremented by the count of pulses on the frame bus, which stops when the frame generates a frame pulse that is supplied to the counter. For example, if frame n-1 is the second frame, the individual counter in frame n-1 receives the frame bus signal which is incremented twice: once for frame 1 and once for frame n-1. When frame n-1 generates the frame pulse, the individual counter stops incrementing, and thus, frame n-1 is identified as the second frame. The total count counter operates to provide a complete count of the system. The total count counter counts the total number of pulses on the frame bus. Once the power bus return signal is activated, that counter stops incrementing, since there are no more frames in the series. By counting the total number of pulses of the frame bus, and knowing when the count stops, the total count counter tracks the total number of frames in the series. Similarly, a counter in each register tracks the number of pulses on the door bus, and can thus identify the operational characteristics of each frame.

10 The particular delay time chosen is not important for an understanding of the present invention but is typically chosen in accordance with the engineering tolerances and component speeds of the pulse generator and delay signal generator 12 and the status register 14. Each delay signal 20, 20' and 20'' are propagated by each circuit 12, 12' and 12'', respectively. Frame n-1 receives the delayed signal 20 and generates another delay signal at time T_{n-1} . Likewise, Frame n-1, the frame bus signals 24 and door bus signals 26 are generated at this unique time T_{n-1} .

Frame n operates similarly but its frame bus signals and door bus signals 24 and 26 are delayed until time T_n .

The pulse generator and delay signal generator 12 described herein may comprise custom or conventional pulse and delay signal generation circuitry, which are readily understood by those skilled in the art. For example, the circuit 12 may comprise a conventional pulse generator and RC circuit of a predetermined time constant to generate the pulse signals and the delayed power on input signal described herein. Likewise, the status register 14 for each frame may comprise conventional memory systems and comparators for monitoring the condition on the bus 16 and the power on input signal 18. It is intended that the status register described herein is a general purpose register adapted with one or more counters to achieve the functionality stated herein.

The status register 14 for each frame as shown in Fig. 1 receives data from the multi-channel data bus 16 and stores that information locally. Those skilled in the art will recognize that the multi-channel data bus 16 could be expanded to include the status state of other operational characteristics in addition to the door status depicted. Moreover, each status register may be further adapted with status LEDs to give users a visual indication of each of the status indices obtained by the register, and/or frame ID status, and/or total frame count. Additionally, each status register may be coupled to a master status register (not shown) which monitors the status of all the frames in the tape library system.

Figures 3A-3D depict flowcharts of the exemplary frame detection, identification and status monitoring process according to the present invention. In Figure 3A, a setup flowchart 50 is depicted. Initially, a first and last frame members (steps 52 and 54) are defined a priori. In the present exemplary embodiment, the first frame receives a power on signal and generates the first

delayed power on signal, and the last frame generates the power bus return signal, thereby ending the count. Also, since the determination of individual frame identification and total frame count relies on a cumulative count of the time delayed power bus signals provided, the delay time for each frame is established to within acceptable tolerances 56. For simplicity, a 5 constant (global) delay time can be established for all the frames. Alternatively, each frame can have a unique delay time.

Figure 3B depicts a flowchart 60 of the signals generated by each frame for identification and status monitoring. All the frames in the library are coupled to a multi-channel bus which may comprise a power bus, a frame bus, a status bus (e.g., door status bus) and a return power bus 62. When any frame is powered on 63, each status register receives this signal and resets the registers 64 (or, more precisely, each counter is zeroed). In the first frame, the signal on the power bus is received, and the first frame generates a delayed signal at a predetermined time (i.e., at time T_1 in Figure 2) 66. The first frame also generates a status signal (e.g., door open status signal) and a frame signal having a delay time equal to the delay of Frame 1, and these signals are placed on the door bus and frame bus, respectively 68. Likewise, a frame pulse is supplied to the register of Frame 1 (70) for counting purposes. The delayed signal generated in the first frame is supplied to the next frame in the series 72, which in turn generates its own delayed signal having a delay time equal to the delay time chosen for that frame. This next frame generates a status signal and a frame signal having a delayed time equal to that frame, and 20 these signals are placed on the door bus and frame bus, respectively 74. Likewise, a frame pulse is generated and supplied to the register of that frame 76. This process is repeated n times, once for each frame in the system. At the last frame, when the delayed signal is generated, a power

bus return signal is activated and placed on the power bus return bus, indicating an end to the count 78.

Figures 3C and 3D represent flowcharts 80 and 100 for determining the individual frame ID, and the total count of frames in the library system, respectively. To determine the ID of an individual frame 82, a frame reads the pulses on the frame bus to increment the individual count counter in the status register 84. Each time a pulse is generated on the frame bus, the individual counter is incremented 86. This process continues until the frame generates a frame pulse. Once a frame pulse is generated and supplied to the individual counter, the register sets the count in the individual counter 88, thus generating each frame's ID with respect to the other frames. To determine the total frame count 102 (Figure 3D), a frame reads the pulses on the frame bus to increment a total count counter in the status register 104, and each time a pulse is generated on the frame bus, the total count counter is incremented 86. The register determines if the last frame has generated a power return signal (by monitoring the power return bus) 108. If not, the total count counter continues incrementing 106. If a power return signal is present, the total count counter freezes the count 110, and the total number of frames is determined by the data in the counter. Although not expressly shown, each frame can similarly monitor the status (e.g., door open status) of the other frames since this data is likewise available on the common bus.

Those skilled in the art will recognize numerous modifications may be made to the present invention, without departing from the spirit and scope of this invention. For example, the description above of Fig. 2 assumed that the time frames $T_0 - T_n$ are equal. However, the present invention can be adapted where the individual time frames are not equal to one another. Moreover, the signals depicted in Fig. 2 need not be square wave signals of definite duration, but may rather be simple pulses, or other signals sufficient to trigger the counter events as detailed

above, as will be readily understood to those skilled in the art. Moreover, the circuitry depicted in Figure 1 could be equally adapted, in whole or in part, to generate signals with the opposite polarity than depicted in Figure 2. It will also be understood that although the drawings depict a plurality of frames connected together adapted with the circuitry shown, other configurations are contemplated. For example, each frame need not necessarily be adapted with a register, but rather may be a frame adapted for another purpose that is added onto the bus as another node. Other modifications can be made. The individual ID counter described herein could be replaced with a general-purpose register, where the frame pulse signal 30 is used to transfer the current contents of the frame counter register into the individual frame ID register. Thus, as used herein, counters and registers may be used interchangeably. These and other modifications will become readily apparent to those skilled in the art and all such modifications are deemed within the spirit and scope of the present invention, only as limited by the appended claims.